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VACUUM DEPLOYMENT TESTS ON AN EXPANDABLE CREW TRANSFER TUNNEL

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ARO, Inc.

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FOREWORD

The work reported herein was done at the request of the Air Force Aero-Propulsion Laboratory (AFAPL), Research and Technology Division (RTD), Air Force Systems Command (AFSC), Wright-Patterson Air Force Base, Ohio under Program Element 62405214, Project 8170.

The expandable crew transfer tunnel tested for AFAPL was designed and fabricated by Goodyear Aerospace Corporation, Akron, Ohio, under Contract AF33(615)-2114.

The results of tests presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract AF40(600)-1200. The tests were conducted from December 14, 1965 to January 6, 1966 under ARO Project No. SM0602, and the manuscript was submitted for publication on March 8, 1966.

This technical report has been reviewed and is approved.

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ABSTRACT

An inflatable crew transfer tunnel, packaged in a canister, was tested in a simulated environment of 10^{-5} torr. The canister separation, tunnel deployment, and pressurization were successfully accomplished. A tunnel leakage rate was established over a 24-hr period with the tunnel pressurized to 0.5 atm while in the simulated environment of 10^{-5} torr.

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SECTION I
INTRODUCTION

Expandable structures are an important part of the manned space program[1]. All variations of this concept are characterized by a packaged structure many times smaller than its deployed configuration. Four scale models of cylindrical self-rigidizing structures were recently tested in the Aerospace Research Chamber (12V).

This report covers the testing of an inflatable crew transfer tunnel designed and fabricated by the Goodyear Aerospace Corporation. The tunnel is made from 11 separate layers of materials. It is packaged in a canister which will be remotely ejected once the space vehicle and space laboratory are in orbit. The tunnel will be deployed and pressurized to approximately 0.5 atm. This will permit astronauts to transfer from the space vehicle to the space laboratory without being exposed to any potential hazards of outer space. This test was conducted in the Aerospace Environmental Chamber (Mark I) at the Aerospace Environmental Facility (AEF), AEDC.

The test objectives were to: (1) determine the stress loads in the canister separation screws by the packaged tunnel applying some additional pressure against the canister during vacuum chamber pump-down to 10^{-4} torr, (2) demonstrate the functional separation of the canister and deployment of the unpressurized expandable tunnel at 10^{-4} torr or lower, and (3) determine the appearance of the tunnel and the leakage from the tunnel during a 24-hr period while pressurized to 0.5 atm at 10^{-4} torr or lower. All test objectives were successfully accomplished.

SECTION II
APPARATUS

2.1 MARK I

2.1.1 General Description

Mark I consists of a large cylindrical vacuum tank, pumping systems, thermal environmental systems, vibration system, controls,

[1]Aerospace Expandable Conference Transactions. Air Force Aero-Propulsion Laboratory, (AD432006), October 23-25, 1963, Dayton, Ohio.

and instrumentation suitable for conducting tests on large space vehicles. A schematic of the facility is shown in Fig. 1. The chamber and associated equipment areas are shown in Fig. 2. The chamber is contained in a room 68 by 68 by 109 ft high. Service areas within the building provide space for test article buildup and equipment maintenance.

Mark I (Fig. 2) is a cylindrical vessel 42 ft in diameter and 82 ft in height with 0.875-in.-thick walls and 1.5-in.-thick elliptical heads. The chamber shell is constructed of 304 L stainless steel to give low outgassing and good corrosion resistance.

The inside working dimensions of the chamber are 35 ft in diameter and 65 ft in height. Vehicle entrance to the chamber is through a 20-ft-diam hatch located in the top of the chamber. Personnel access to the chamber is through a hatch 8 ft in diameter near the bottom of the chamber.

Three pumping systems will be available for evacuating the Mark I chamber: (1) a three-stage increment of the Propulsion Wind Tunnel Facility (PWT) plenum evacuation system, (2) a conventional vacuum pumping system consisting of roughing pumps, fore pumps, booster pumps, and diffusion pumps, and (3) a cryopumping system cooled by 90-kw liquid nitrogen and a 7.5-kw gaseous helium system.

2.1.2 Pumping System Used for This Test

The pumping system used for this test consisted of two 850-cfm roughing pumps and four mechanical fore pumps to evacuate the chamber from atmosphere to 15 torr, where two 4000-cfm roots blowers were started; at 10^{-1} torr four booster pumps were placed in operation; and at 10^{-2} torr the roughing pumps and roots blowers were valved out, and two 32-in. diffusion pumps were placed in operation. Approximately 100 ft^2 of LN_2 cryopumping surfaces was used. Figure 3 shows the pumpdown curves obtained with this system.

2.2 TEST VEHICLE

The test vehicle (Fig. 4), an inflatable expandable crew transfer tunnel, was packaged inside a canister and mounted to a carrier bed (Fig. 5), which contains two hatches to simulate the space vehicle and space laboratory hatches. The canister was fastened to the carrier bed with canister separation screws installed in guillotines, which cut the screws and allowed canister separation to take place. The carrier bed was mounted in the test carrier support frame.

The tunnel was made of 11 separate layers of materials. The inner bladder consisted of three layers of nylon, a 1/16-in. layer of foam, and another layer of nylon. Next to the bladder are four layers of Dacron®, a 2-in. layer of polyether foam, and an outer cover of nylon cloth painted with a white rubber paint. Inside the tunnel there are lines on either side to aid the astronaut in crawling through the tunnel.

2.3 TEST CONFIGURATION

Figure 6 shows the test article being lowered into the Mark I test chamber. The test article (Fig. 7) is shown in the test carrier support frame in the test chamber ready for canister separation and tunnel deployment. Figure 8 shows the control panel where the test data were monitored and recorded. Four cameras mounted on stands outside three viewing ports were used to obtain high speed and standard speed motion pictures of the canister separation and tunnel deployment and pressurization. A closed-circuit television located inside the test chamber monitored the canister separation, tunnel deployment, and pressurization.

2.4 INSTRUMENTATION

Chamber pressure was monitored by two alphatrons and three ionization gages. The tunnel internal pressure was monitored by two transducers and an absolute mercury pressure gage. Iron-constantan thermocouples were used to monitor the tunnel wall foam temperature. Strain gages were used to monitor the loads in the canister separation screws during chamber pumpdown. A 25-channel data logger system, strip chart recorders, and multipoint recorders were used to record the test data. Canister separation, tunnel deployment, and pressurization were monitored by a closed-circuit television and recorded by four motion-picture cameras.

SECTION III
PROCEDURE

3.1 PREPARATION OF TEST MODEL

The deployed tunnel is shown in Fig. 9 prior to being packaged. Solenoid valves were attached to lines leading to both hatches. Using vacuum pumps, the tunnel and the 2-in. foam layer were evacuated to

2 to 3 psi below atmospheric pressure and folded as shown in Fig. 10. The canister was then placed over the tunnel and fastened to the carrier bed with 12 separation screws (Fig. 5). The screws were each mounted through guillotines which were used to cut the screws, permitting canister separation and tunnel deployment. The carrier bed with tunnel and canister was then hoisted and fastened to the test carrier support frame (Fig. 7). A canvas catcher was installed to the support frame to catch the canister after deployment (Fig. 7). The assembled test specimen was then placed in the test chamber, and all instrumentation and pressure lines were connected (Fig. 7). Test equipment and instrumentation were checked prior to starting the actual test.

3.2 TEST PROCEDURE

The normally closed solenoid valves were energized to allow the gas in the packaged tunnel to escape into the chamber during pumpdown. Still photographs were taken of the test specimen (Fig. 7), and initial strain-gage readings were recorded. Chamber evacuation was then started.

During chamber pumpdown, vacuum chamber pressure (Fig. 3), tunnel wall foam temperature, solenoid valve temperatures, tunnel internal pressure (Fig. 3), and separation screw loads were monitored and recorded.

Tunnel wall foam temperature was to be maintained above 50°F, and solenoid valve temperature was to be maintained below 200°F during pumpdown. The separation screw loads were not to exceed 200 lb/screw.

When the chamber stabilized below 10^{-4} torr, the solenoid valves were de-energized, and the tunnel was ready for deployment. With the tunnel wall foam temperature above 50°F and the chamber pressure below 10^{-4} torr, the chamber lights were turned on, and motion-picture cameras were started. One second later, the 12 pyrotechnic guillotines were simultaneously fired. The guillotines cut the canister separation screws, the canister fell into the canvas catcher on the test carrier, and the tunnel started to deploy.

Deployment of the tunnel was completed by inflating it with carbon dioxide. The tunnel was pressurized to 0.5 atm, and the chamber lights and cameras were turned off. The tunnel temperature and pressure were allowed to stabilize over a 2-hr period, and the tunnel

leakage was measured over a 24-hr period. The tunnel internal pressure, foam wall temperature, and chamber pressure were recorded initially and at 0.5-hr intervals during the 24-hr leakage test. At the end of the 24-hr period, the chamber and tunnel were both returned to atmospheric pressure. The test article was disconnected from the penetration flanges, removed from the test chamber, disassembled, and packaged for shipment.

SECTION IV
RESULTS AND DISCUSSION

4.1 RESULTS

The test data obtained from these tests consisted of motion pictures of the canister separation, tunnel deployment, and pressurization. Chamber pressure, tunnel internal pressure, and wall foam temperature were recorded during the chamber pumpdown and the 24-hr leakage test. The loads on the canister separation screws were recorded during chamber pumpdown. Results indicate that all test objectives were successfully accomplished.

4.2 DISCUSSION

4.2.1 Canister Separation, Tunnel Deployment, and Pressurization

Figure 7 shows the tunnel prior to canister separation. The canister separation was accomplished at a chamber pressure of 3.2×10^{-5} torr (Fig. 3) and a tunnel internal pressure of 4 torr. The canister separation was recorded by four separate motion-picture cameras. Separation was recorded from a chamber port viewing the tunnel broadside at 400 and 24 frames/sec. The separation was also recorded from chamber ports viewing each end of the tunnel. Tunnel deployment and pressurization were recorded by the same four cameras. Figure 11 shows the tunnel during three different stages of deployment and pressurization.

4.2.2 Chamber and Tunnel Internal Pressure

The curve on the left of Fig. 3 shows how the tunnel pressure followed the chamber pressure during the pumpdown prior to deployment. The flat spots on the initial pumpdown curve at 10^{-3} and 2×10^{-4} torr are the results of leaks in the chamber that developed and were temporarily repaired during the pumpdown. This curve also shows the repressurization of the tunnel prior to the 24-hr leakage test.

The curve on the right of Fig. 3 shows the second pumpdown and the 24-hr leakage test. During the 24-hr test, the tunnel internal pressure decreased from 397 to 362 torr. The total leakage during the 24-hr period was 0.54 or 2.25×10^{-2} lb/hr. The chamber pressure was 5.5×10^{-5} torr at the start of the 24-hr test and gradually decreased to 2.4×10^{-5} torr at the conclusion. Figure 12 shows the pressurized tunnel after completion of the 24-hr leakage test.

4.2.3 Tunnel Wall Foam and Solenoid Valve Temperature

The tunnel wall foam temperature was 82°F at deployment and increased to 129°F because of the heat load from the chamber lights, which were required for motion-picture coverage. During the 24-hr leakage test, the tunnel wall foam temperature increased from 90 to 92°F. These temperatures are all satisfactory since the requirement was a minimum allowable temperature of 50°F. The solenoid valves were easily maintained at temperatures below the 200°F maximum allowable.

4.2.4 Loads in Canister Separation Screws

The strain gages indicated a very negligible load change, compared to the 200 lb allowable, on the canister separation screws during chamber pumpdown.

SECTION V
CONCLUSIONS

Canister separation, deployment, and pressurization of the tunnel in a simulated environment of 10^{-5} torr were very successful. A nominal amount of leakage was recorded from the tunnel during the 24-hr test period while pressurized to approximately 0.5 atm and maintained in a simulated environment of 10^{-5} torr. The leakage rate was considered to be satisfactory.

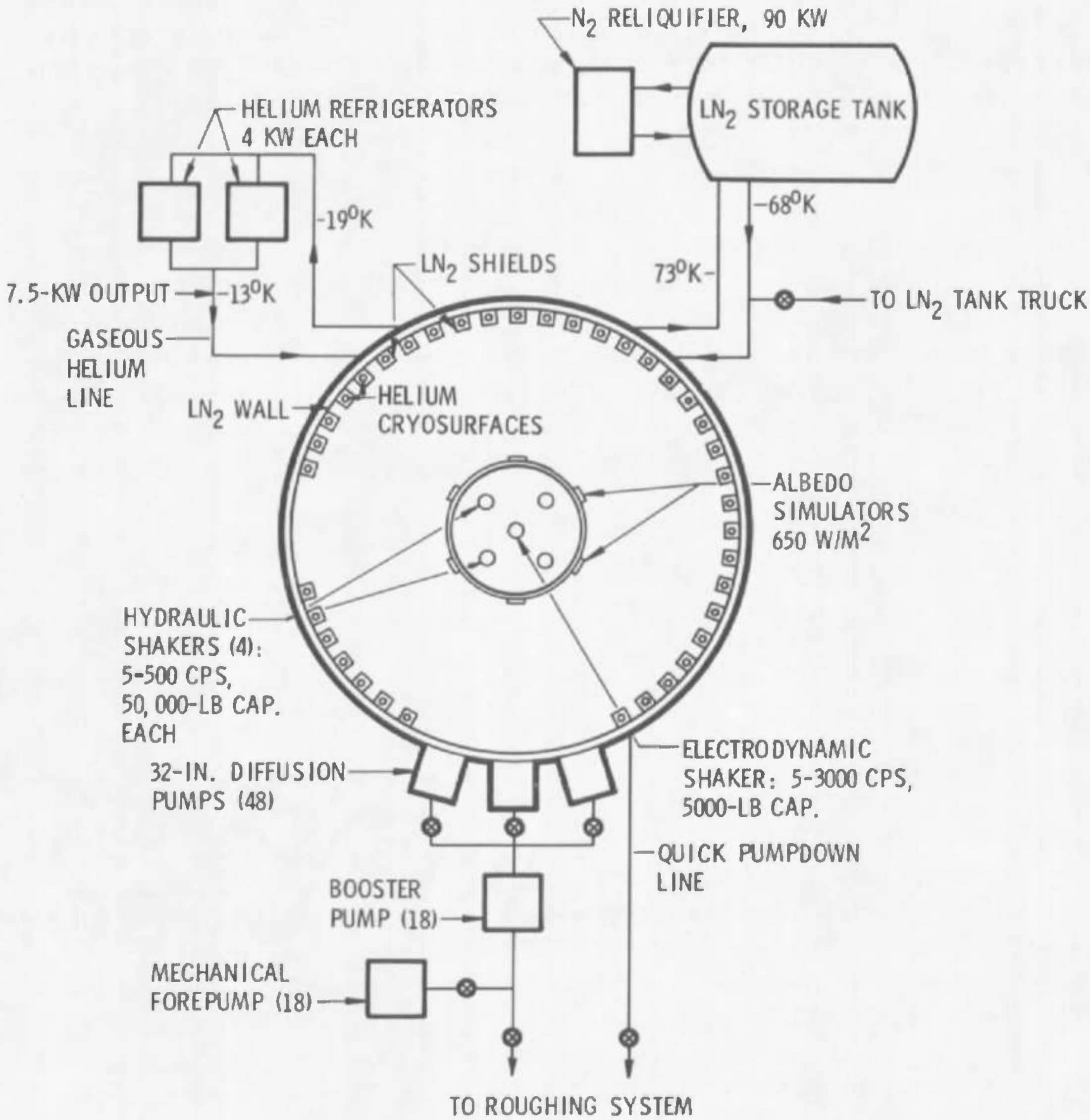

Fig. 1 Mark I Schematic

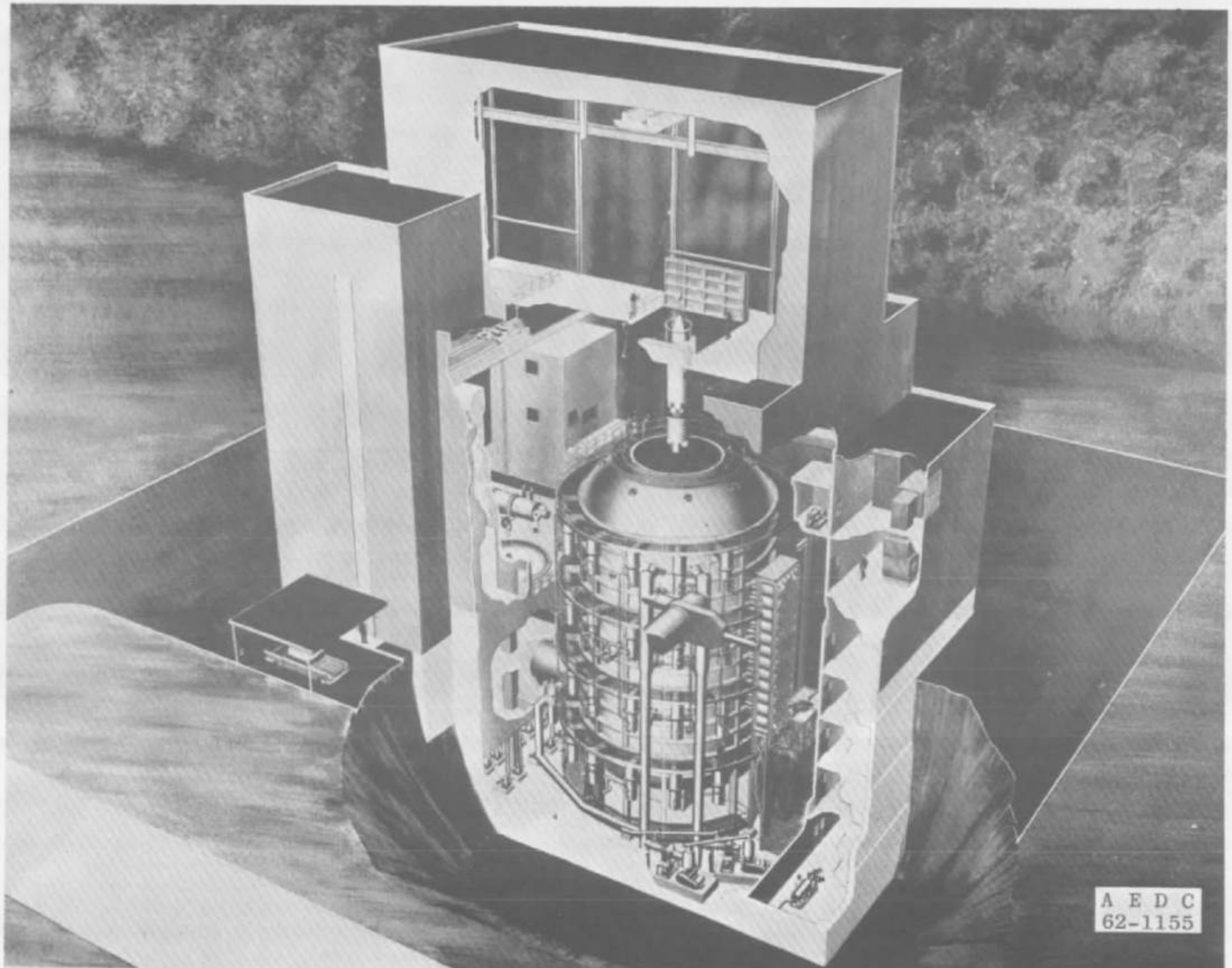

Fig. 2 Mark I Facility Arrangement

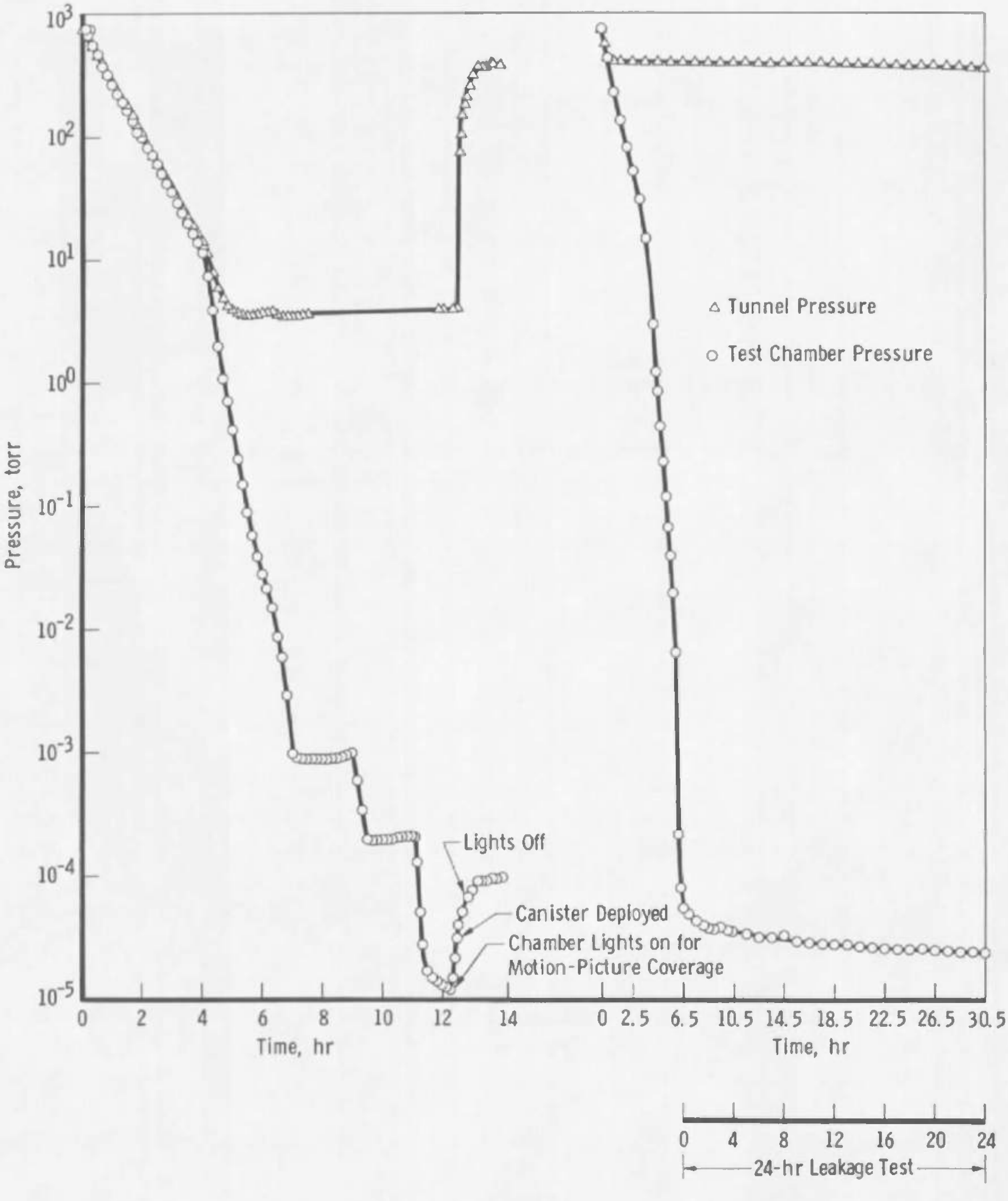

Fig. 3 Chamber and Internal Tunnel Pressure

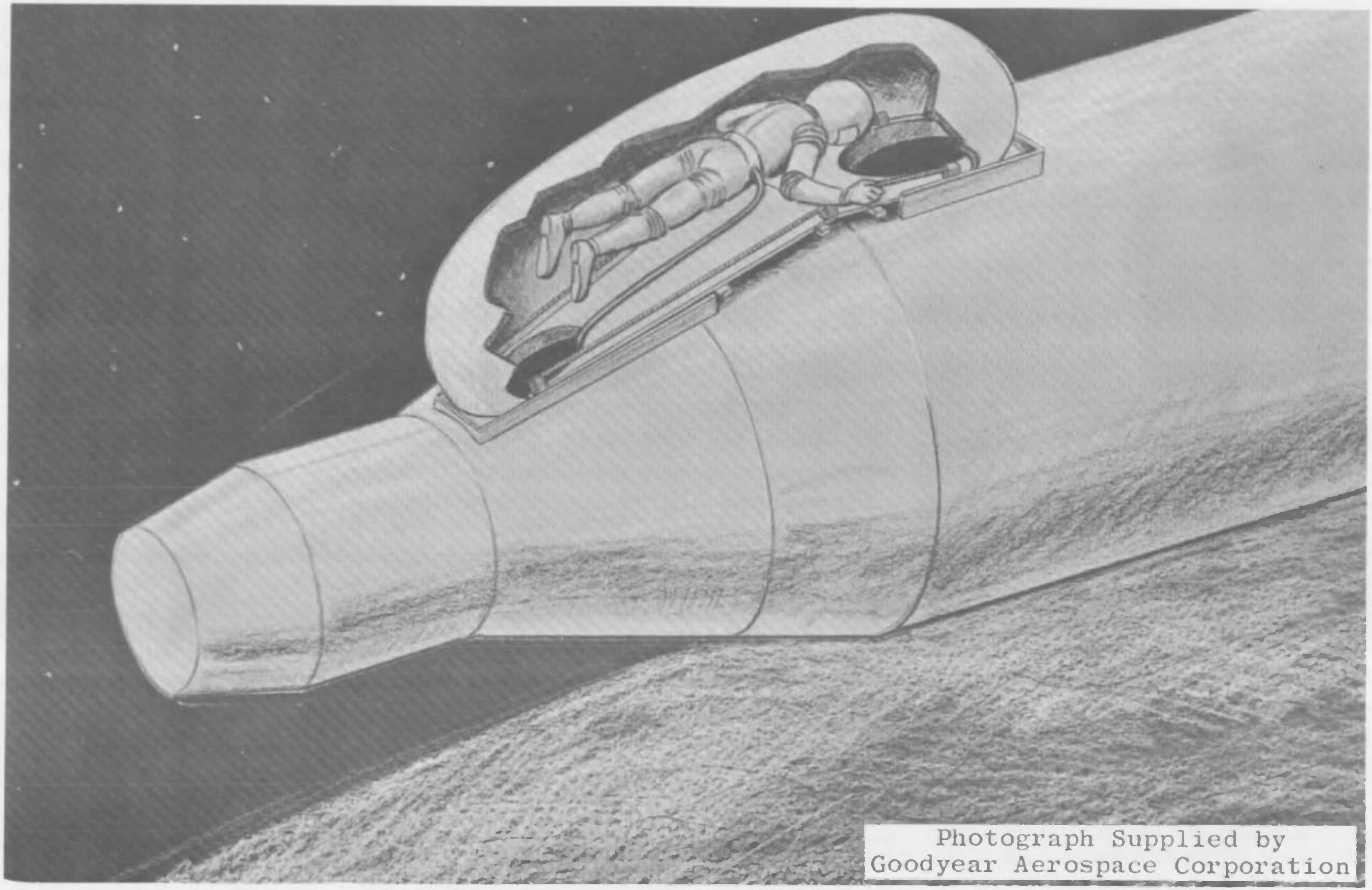

Fig. 4 Inflatable Crew Transfer Tunnel

Fig. 5 Packaged Tunnel inside Canister Mounted on Carrier Bed

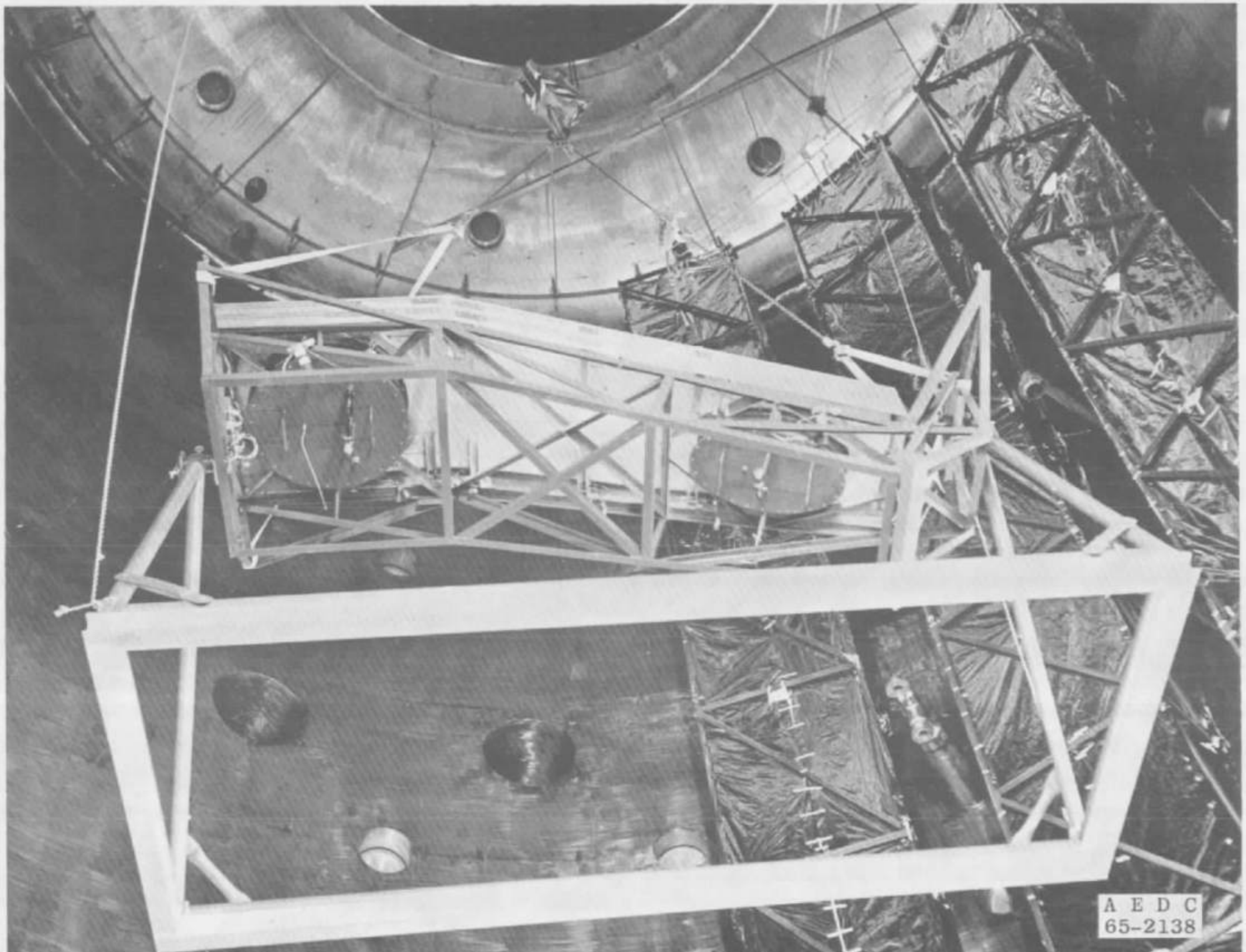

Fig. 6 Assembled Tunnel Being Lowered into Test Chamber

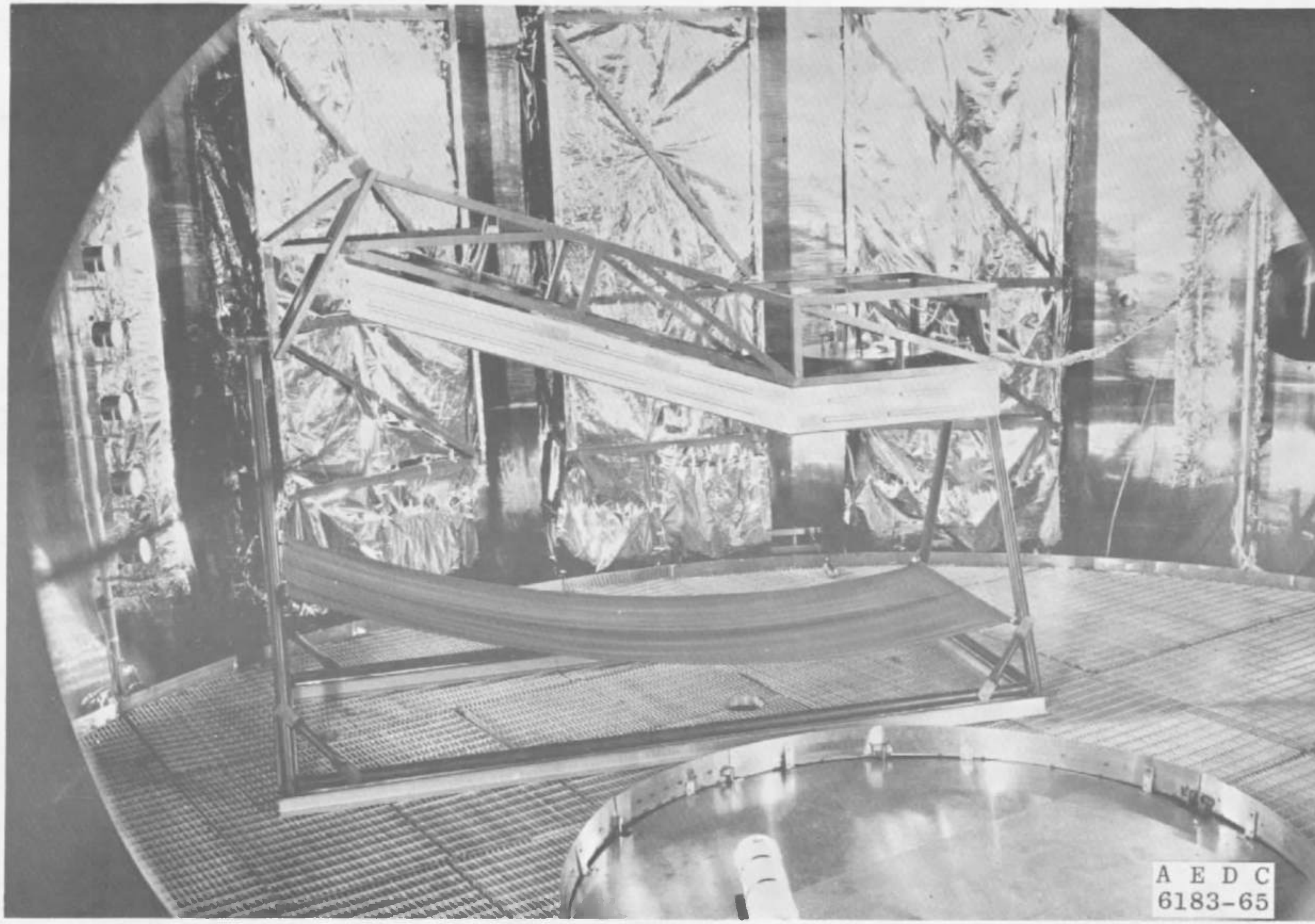

Fig. 7 Tunnel Installed in Test Chamber

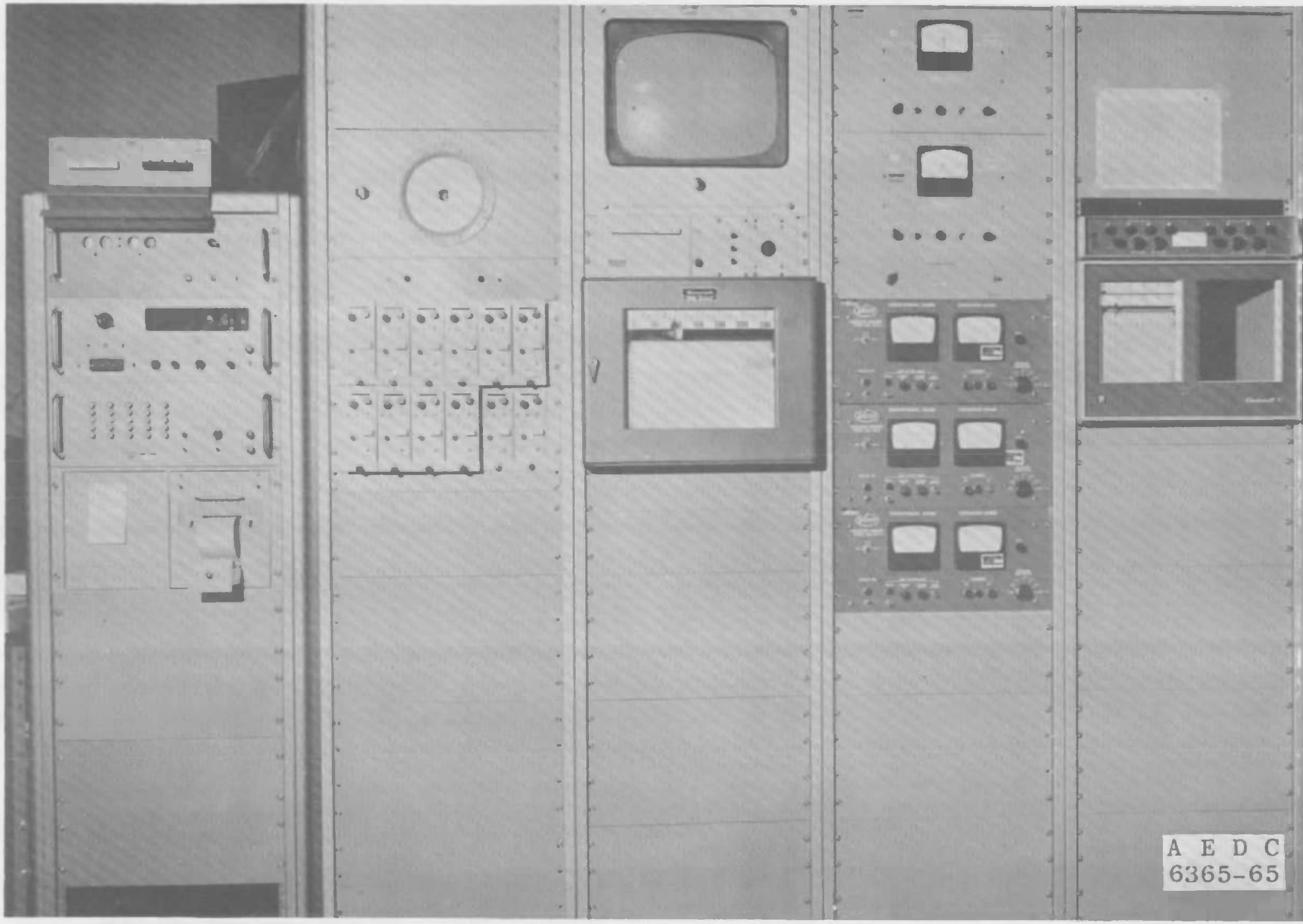

Fig. 8 Control Panel and Instrumentation Readouts

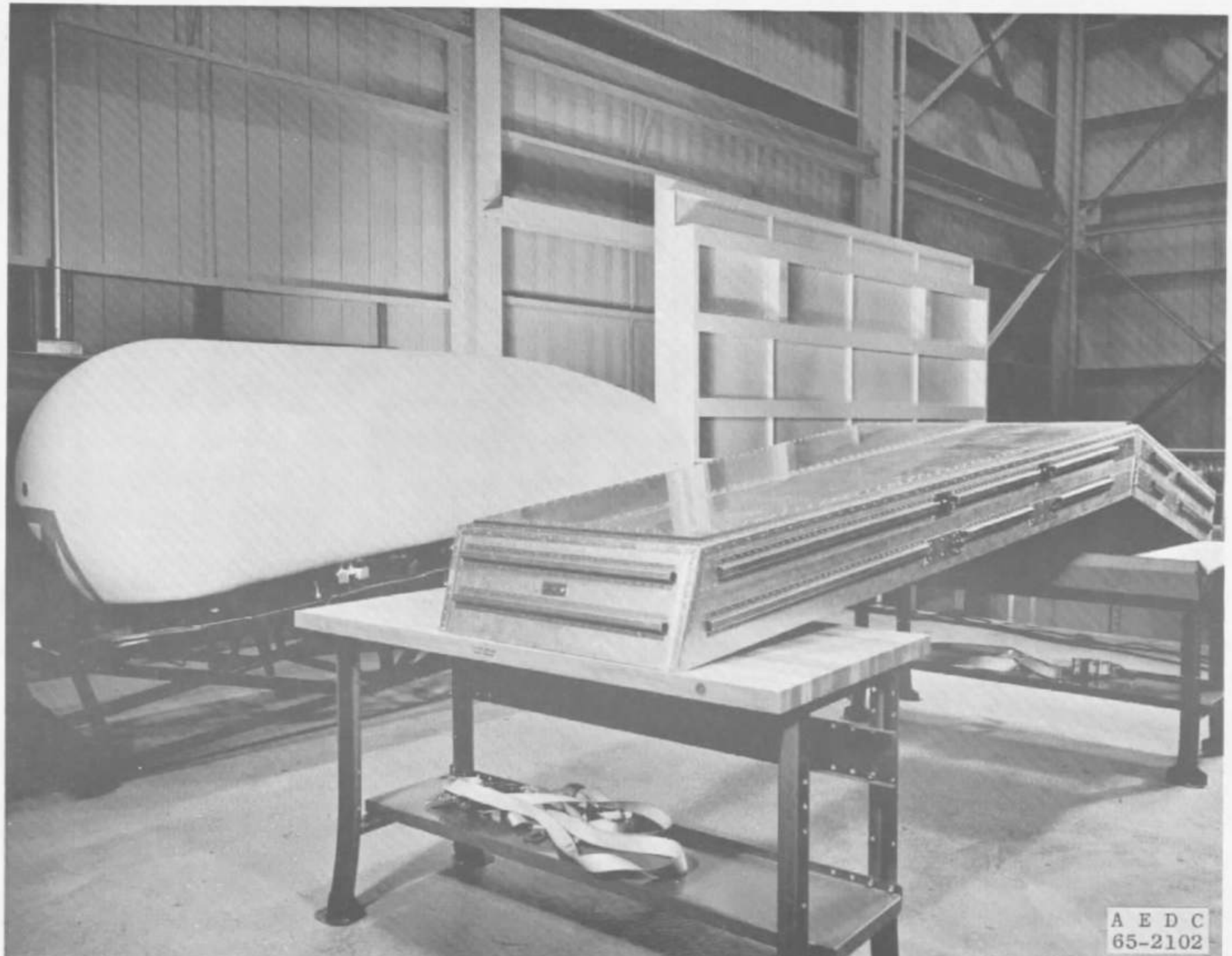

Fig. 9 Deployed Tunnel prior to Being Packaged

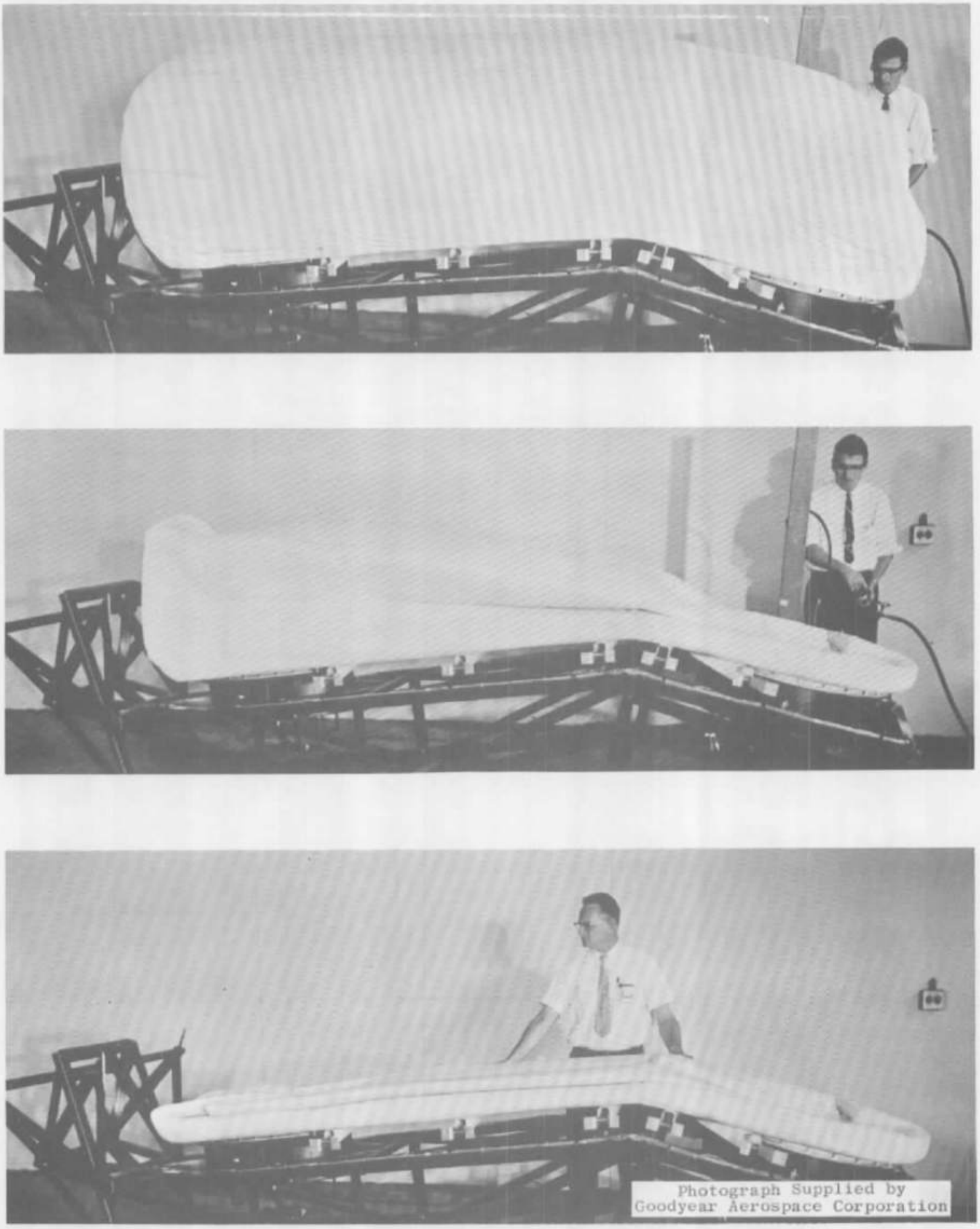

Fig. 10 Tunnel Packaging

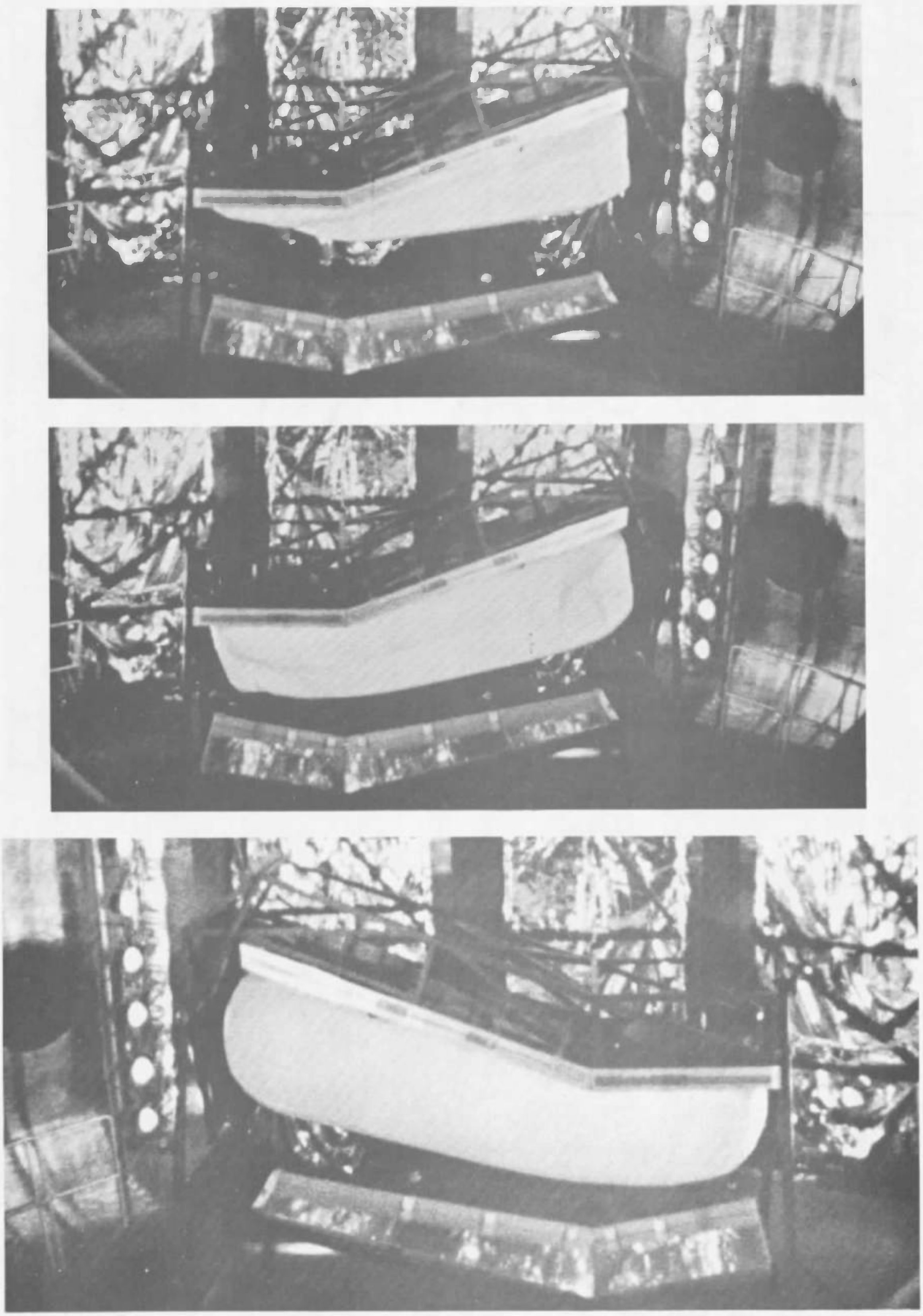

Fig. 11 Tunnel Deployment

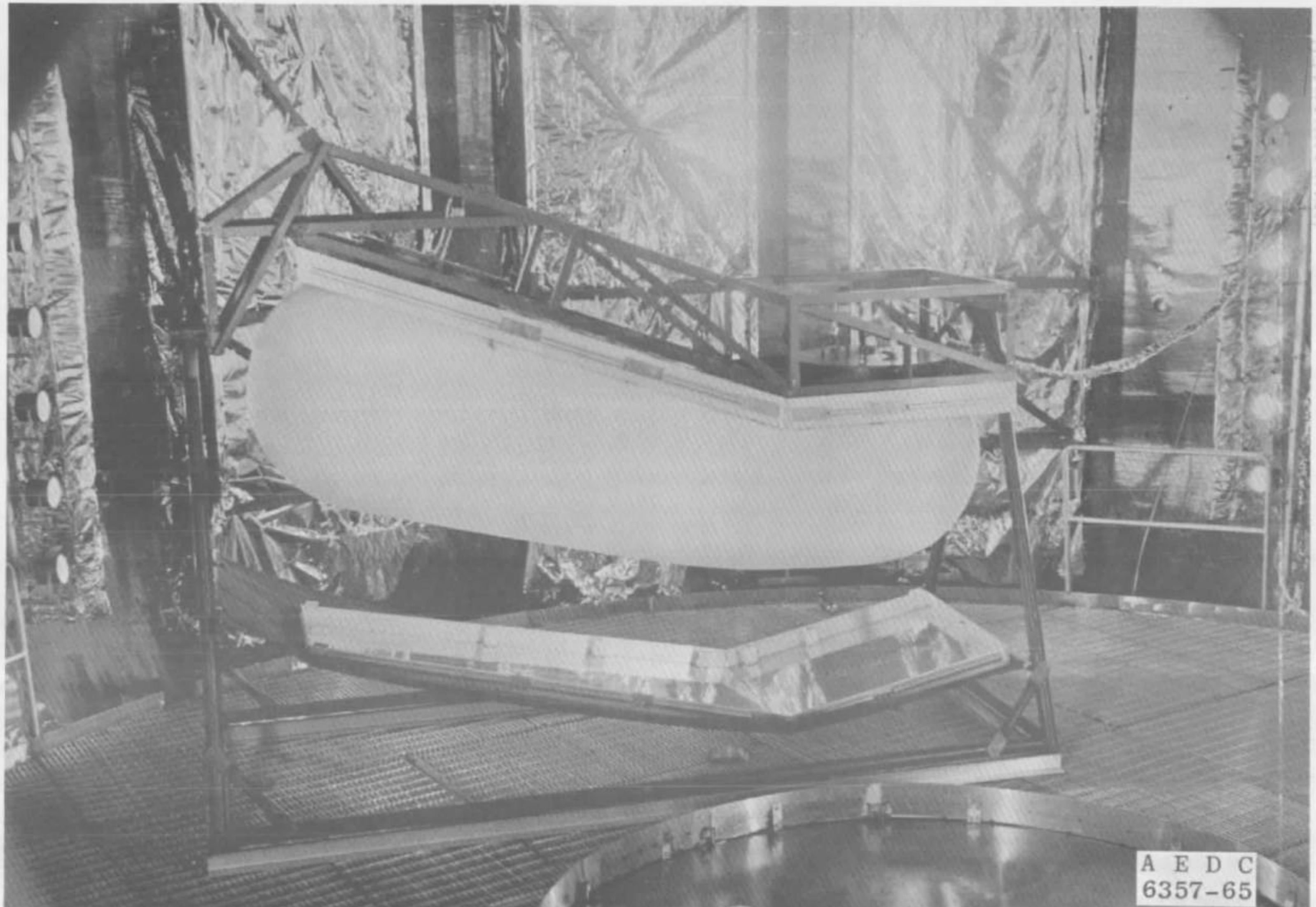

Fig. 12 Pressurized Tunnel after Completion of the 24-hr Leakage Test

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~~environmental tests~~						
3 canisters separation						
4 tunnels deployment						
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1-2

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